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Insect-caused mortality

in relation to methods of cutting in Ponderosa Pine on the Blacks Mountain Experimental Forest

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FOREST AND RANGE
EXPERIMENT STATION

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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

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IN PONDEROSA PINE ON THE

BLACKS MOUNTAIN EXPERIMENTAL FOREST

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ABSTRACT

Bark beetles have long been recognized as a major factor to be contended with in perpetuating ponderosa pine through forest management. In the ponderosa-Jeffrey pine type (locally called "eastside pine") of northeastern California, the destruction wrought by bark beetles in unmanaged, old-growth timber is well known.

During the past half century, a variety of timber-harvesting methods have been used in logging much of California's old-growth ponderosa pine. The effect of the harvesting method on insect-caused mortality has been one of the unanswered questions confronting the forest manager. Conceivably, the method of cutting might profoundly influence the course of damage due to bark beetles for many years after logging; or it might have little or no effect. To determine which of these alternatives most nearly applies in the management of ponderosa pine in California, mortality data from a methods-of-cutting study, in progress on the Blacks Mountain Experimental Forest, were analyzed. The results suggest that once the susceptible trees are logged, sharp reductions in the volume of timber killed can be expected, regardless of the harvesting method. They provide good reason for believing that logging high-risk trees is effective for a much longer period than once thought.

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INSECT-CAUSED MORTALITY IN RELATION TO METHODS OF CUTTING IN PONDEROSA PINE ON THE BLACKS MOUNTAIN EXPERIMENTAL FOREST

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INTRODUCTION

Research on the management of ponderosa and Jeffrey pine in the eastside pine forests of northeastern California has been in progress at the Blacks Mountain Experimental Forest, Lassen County, for more than 20 years (Hallin, 1959). One of the special investigations being conducted there by the Station's Division of Forest Management Research is a study of methods of cutting old-growth pine stands. Following the establishment of the Experimental Forest in 1934 (Anonymous, 1938a), plans were formulated by Duncan Dunning (1937) and A. A. Hasel (1938) to test a selected few of the systems of cutting then advocated in ponderosa pine management. The general purpose of this work was to determine the ultimate value of the different cutting systems in achieving maximum sustained yield from the low-site quality eastside pine forests. To this end the Division established and logged a series of 20-acre plots by various methods over a ten-year period, starting in 1938.

One of the principal objectives of the methods-of-cutting study, according to Hasel (1938), was to determine the relative merits of the various cutting methods with regard to volume growth, monetary return, restocking rate, improvement in stand structure, and in reduction in mortality. The latter is of special significance to forest entomologists, for a large proportion of the mortality in eastside pine stands normally is due to insects. A cutting method that would appreciably reduce insect-caused losses would have obvious advantages, other conditions being equal. Conversely, it would be important to know if a cutting method tended to induce such losses. For this reason, entomologists began collecting records of mortality on the plots from the start of the tests. These records were taken yearly, once the plots were cut, from 1939 through 1954.

Recently, the mortality records were analyzed by the Station's Division of Forest Insect Research. The purpose was to determine: (1) if insect-caused losses were correlated with method of cutting; and (2) if differences in losses by method were great enough to warrant continuing annual measurements. This report contains an analysis of the mortality data obtained, and summarizes the results and conclusions derived therefrom.

Many persons helped gather the information on which the report is based. Although they cannot all be individually credited here, their assistance is acknowledged. Special credit is due J.W. Bongberg

who was responsible for measuring the annual losses caused by insects on the plots until 1952, to M. M. Furniss who carried on this work for two years thereafter, and to G. L. Downing who began the analysis of the data. The entomological phases of the study have been conducted by the Division of Forest Insect Research (until 1954, the Berkeley, California, Forest Insect Laboratory, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine). Data and information about the methods-of-cutting study, except that pertaining to mortality, were furnished by the Division of Forest Management Research, unless otherwise stated.

EXPERIMENTAL DESIGN

The design of the methods-of-cutting study is described in detail in the plan prepared by Hasel (1938). Briefly, the plan called for a randomized block arrangement in which each treatment would appear only once. Blocks were to be replicated yearly over a 10-year period. They were to be uniform within themselves and representative of major forest conditions. Within each block the treatments were to be assigned to the plots at random. A 10- by 20-chain plot size was specified, each plot to be surrounded by an isolation strip at least 1 1/2-chains wide. In carrying out the study, the essential features of the experimental design, as specified in the plan, were adhered to rather closely.

The experimental design contains certain inherent weaknesses for studies of insect-caused mortality. Most important of these are the small number and size of the plots, the staggered time of plot establishment, and the close proximity of treatments within blocks. It should be borne in mind, however, that the experiment was not planned for mortality studies alone, but was designed to yield information on a variety of problems relating to pine management, of which mortality is only a part. While the design quite probably is satisfactory for some of the objectives aimed for, its adequacy for studies of insect-caused losses is open to question.

METHODS-OF-CUTTING TREATMENTS

The plan for the methods-of-cutting study called for four treatments, i.e., three cutting methods and an uncut control (Hallin, 1959). Over the 10-year period during which the study was established, however, other cutting methods were added, so that in all, seven treatments are represented in the experiment. In this report only six of these treatments are considered. The seventh, Unit Area Control, was superimposed on one of the other treatments 10 years after the experiment began. Discussion of the method is omitted, because after the second cut was made, mortality data from the plots cut by both methods could not be identified with either treatment.

Following is a brief description of each of the treatments tested. The first four were specified on the original plan, whereas the last two were added later.

1. Control (C) - No cutting done (Hasel, 1938).

2. Heavy Forest Service (HFS) - Approximately 80 percent of the volume in trees 11.6 inches in diameter breast high (d.b.h.) and larger to be removed. Include most of the Dunning class 3, 4, and 7 trees, and all of the class 5 trees. Best of the Dunning class 3 and 4 trees, and in general all of the class 1, 2, and 6 trees to be retained. (Anonymous, 1938b; Bongberg, 1939; Hasel, 1938).

3. Modified Forest Service (MFS) - Approximately 40 percent of the volume in trees 17.6 inches d.b.h. and larger to be removed. Include all insect-susceptible (high risk) trees above the minimum diameter limit removed, all Dunning class 4 and 7 trees, and all but best class 5 trees. Low-risk trees in Dunning class 1, 2, 3 and 6 to be retained. (Anonymous, 1938b; Bongberg, 1939; Hasel, 1938; Salman, 1938).

4. Silvicultural-Selection (SS) - All high-risk trees to be cut. When the volume of high risk is less than 2,500 board feet per acre, enough additional low-risk trees to be removed to make up the difference. (Anonymous, 1938b; Bongberg, 1939; Hasel, 1938; Salman, 1938).

5. Insect Selection (IS)[1] - All high-risk trees to be cut. (Bongberg, 1939; Salman, 1938).

6. Clear-cut (CC) - All trees that would make one or more 16-foot logs, with a 10-inch or larger top, to be removed.

On all of the plots, the plan called for cutting the white fir and incense-cedar larger than 11.6 inches d.b.h.

Testing of the foregoing treatments began in 1938 when the first series of plots were established and cut over. Annually, thereafter, for the next 9 years, treatments were applied to a new set of plots, and these plots were added to the series previously established. The Control, Heavy Forest Service, Modified Forest Service, and Silvicultural-Selection are the only treatments that were included in each year's plot series for the entire 10-year period. Plots treated by the Insect Selection Method were included in the test series during the first five years of the study, but were omitted from 1943 on. Plots treated by the Clear-Cut Method were included in the tests of 1939, 1940, and 1942, but

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1/ Synonymous with sanitation-salvage, the term later applied to cuttings in which all high-risk (i.e., insect susceptible) trees are removed.

were not included in other years. In 1947, and in some subsequent years during the period covered by this report, a Unit Area Control cut was made on some of the plots previously treated by Silvicultural-Selection.

Plot numbers, listed according to treatment and year of plot establishment, are given in table 1. Plot locations are shown on the accompanying map, figure 1. The average volume cut, expressed as a percent of the original stand, and the percent pine in both the original and the reserve stands are listed by treatment in table 2. Before cutting, the saw-timber volume (all species) on most plots was about 19,000 board feet per acre. Generally, pine comprised about 90 percent of this total, with incense-cedar and white fir making up the balance.

COLLECTION AND ANALYSIS OF DATA

A wealth of information concerning the stand was taken on each plot as it was established. Of interest in this study is the fact that all pines above 11.6 inches d.b.h. were numbered and classified. For each numbered tree, species, diameter, and class according to the Dunning, Keen, and insect-risk systems were recorded. In addition, the pines on each plot were rated to be cut or left according to each method of cutting. Then the particular cutting method to be used for individual plots was chosen at random. This was done to avoid bias in selecting the treatment for a given plot.

Mortality on the plots after cutting was measured annually from 1939 through 1954. A 100 percent cruise of the plots was made each year, usually during the early summer, as described by Downing (1956). The dead trees found were recorded according to cause of death, i.e., insect species, wind, lightning, fire, or (where mortality could not be ascribed to any of these causes) unknown. In addition, the tree number, species, diameter, year of death, and a post-mortem rating of tree class, according to Dunning's and Keen's systems, were taken. Post-mortem ratings of tree class did not always agree with the original ones, and in summarizing the data for this report the original ratings have been used. They are probably more accurate since they were applied when the trees were alive.

In arranging the data to analyze the effect of treatment on insect-caused mortality, certain kinds of losses were excluded. They are: mortality for species other than pine, mortality due to causes other than insects, and mortality that occurred during the year of cutting, or within the isolation strips surrounding the plots. They were omitted because their inclusion would tend to obscure the effects of the treatments on insect losses in pine. Insects causing the death of non-pine species (white fir and incense-cedar) are different from those that attack pine, and have

Table 1.--Numbers of 20-acre methods-of-cutting plots by year of plot establishment, and by treatment. Blacks Mountain Experimental Forest

Year of plot establishment	Treatments					
	Control	Clear-cut	Heavy Forest Service	Modified Forest Service	Silvicultural Selection 1/	Insect Selection
1938	38-2	--	38-4	38-1	38-3	38-5
1939	39-5	39-4	39-6	39-3	39-2	39-1
1940	40-2	40-1	40-6	40-4	40-5	40-3
1941	41-4	--	41-2	41-5	41-3	41-1
1942	42-6	42-1	42-2	42-4	42-3	42-5
1943	43-4	--	43-1	43-2	43-3	--
1944	44-1	--	44-4	44-2	44-3	--
1945	45-3	--	45-2	45-1	45-4	--
1946	46-2	--	46-3	46-4	46-1	--
1947	47-2	--	47-1	47-4	47-3	--

1/ All plots except 45-4, 46-1, and 47-3 recut by unit area control between 1947 and 1954.

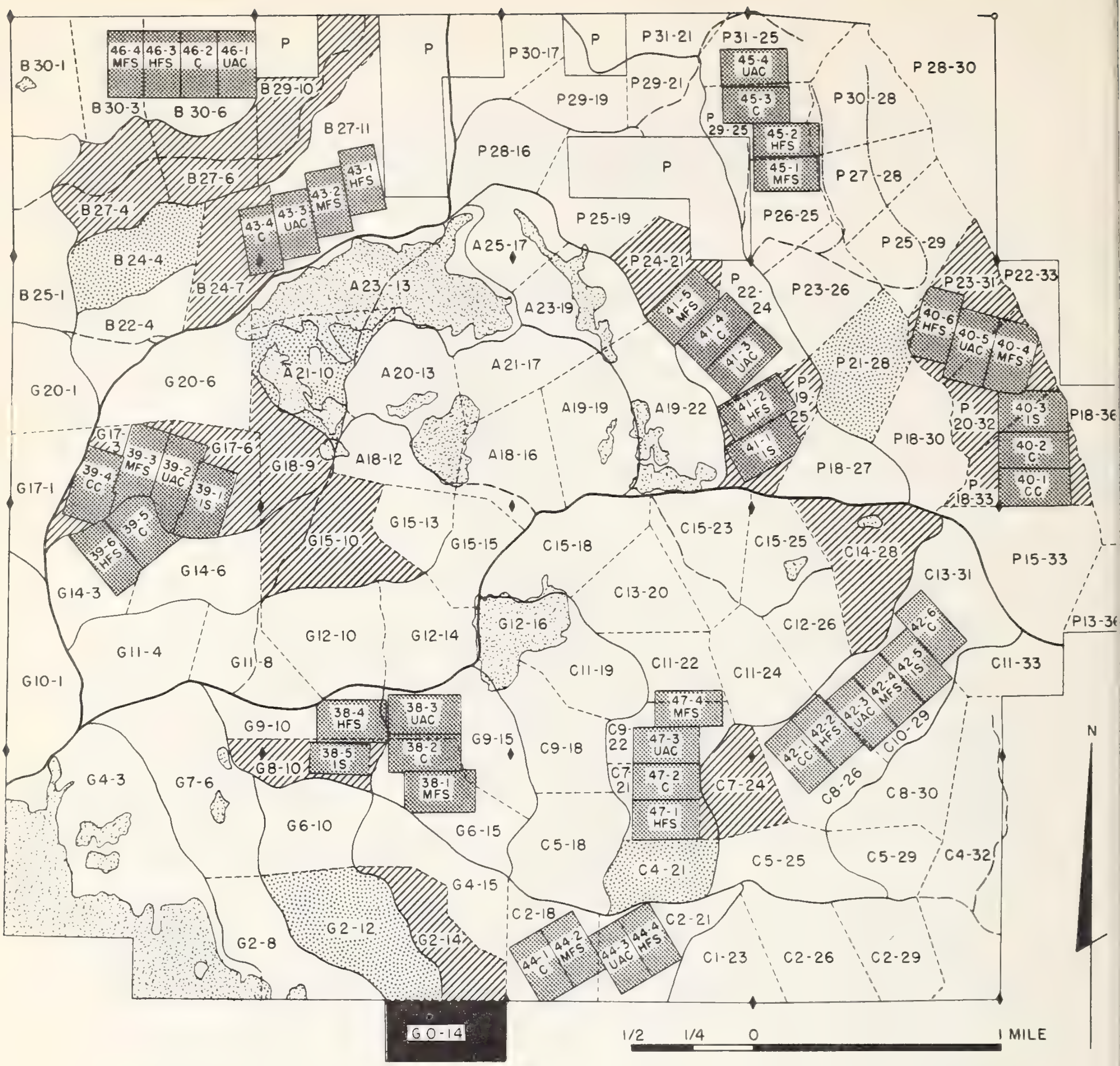

Figure 1

BLACKS MOUNTAIN EXPERIMENTAL FOREST

Road } Compartment boundaries

Secondary road

Proposed road

Nontimbered land

P Patented land

46-4 MFS Method of cutting

AREAS CRUISED ANNUALLY

Natural area

Sani sal cut compartments

20 acre method-of-cutting plots

Entomology special use plot

Table 2.--Percent of stand cut, and percent pine in original and reserve stands, by method of cutting

Method of cutting	Percent of total volume cut 1/	Percent of total volume in pine		Reserve stand pine volume bd-ft./acre
		Original stand	Reserve stand	
Control	0	88.7	88.7	16,436
Clear-cut	94.5	91.0	61.8	559
Heavy Forest Service	73.2	91.9	91.7	4,322
Modified Forest Service	54.8	88.5	85.6	7,085
Silvicultural Selection	16.9	89.1	86.9	13,689
Insect Selection	14.9	93.2	94.7	14,635

1/ Based on original stand at time of plot establishment; includes all species.

a markedly different cycle of abundance. Mortality from causes other than insects is not particularly pertinent to the subject of this report. Mortality during the year of cutting may have been the result of insect attacks started long before cutting took place.

RESULTS

Non-Insect-Caused Loss

Although a detailed analysis of non-insect-caused loss is not within the scope of this report, the relative importance of mortality in this category as compared with mortality due to insects is of interest. Factors other than insects accounted for slightly less than 30 percent of the total volume of pine sawtimber killed on the plots. Nearly half this loss was due to wind, a third to lightning, and the remainder chiefly to unknown causes, including diseases. While there were differences in the mortality from these factors among the treatments, the data for any one factor are too few to be conclusive. On the control plots, mortality due to other causes was one-sixth that due to insects. On the cut plots it varied from three-fifths to twice that due to insects (table 3).

Table 3.--Average volume per acre of pine sawtimber reserve killed annually by insects and other causes, by method of cutting, 1939-1954

Method of cutting	Insects		Other	
	Bd.-ft.	Percent stand[1]	Bd.-ft.	Percent stand[1]
Control	73.6	0.441	12.0	0.072
Clear-cut	0.2	0.036	0.4	0.072
Heavy Forest Service	4.7	0.108	10.0	0.229
Modified Forest Service	6.6	0.093	6.0	0.085
Silvicultural-Selection	5.7	0.041	11.0	0.079
Insect Selection	19.3	0.132	12.0	0.082

1/ Computed by dividing the number of board-feet killed into the weighted mean reserve stand volume.

Insect-Caused Loss

A considerable quantity of information on mortality of pine sawtimber due to insects was gathered in this study. If one year's measurements on a single plot are taken as a plot-year, then over the 16-year period, measuring the 48 plots yearly yielded data for a total of 522 plot-years. Records for three treatments (Control, Heavy Forest Service, Modified Forest Service) are for a total of 115 plot-years apiece. In each of these treatments the same number of plots was established, and the plots remeasured in the same years. For the remaining treatments (Clear-cut, Silvicultural-Selection, Insect Selection) the number of plot-years is variable. Either the number of plots, or the years they were remeasured is lower.

By far the greatest share of the mortality was due to bark beetles. Two species were the chief offenders: the western pine beetle (Dendroctonus brevicomis Lec.) in ponderosa pine, and the Jeffrey pine beetle (D. jeffreyi Hopk.) in Jeffrey pine. They were aided in many cases by the California flatheaded borer (Melanophila californica Van Dyke), which alone, or more often in combination with other bark beetles, attacks both hosts. Pine engravers (Ips spp.) also contributed to the loss to some extent. In this analysis mortality from all of these insects has been pooled; no attempt has been made to separate losses according to insect

species. Chief reason for pooling the data is that most are for ponderosa pine, the predominant tree species, and the western pine beetle, the most frequent cause of tree-killing on the plots.

In developing the mortality data, the plot records were first converted to unit loss per acre per year. The data were then recombined in three ways, to show for each treatment the effect of cutting method on average annual mortality (1) for the entire period of study, (2) for successive number of years after cutting, and (3) for calendar years after cutting. For comparative purposes mortality was expressed in terms of both board feet and percent of stand per acre. Percent of stand is the better unit for most comparisons, as it compensates for differences between treatments in the magnitude of the reserve stand. Obviously the heavier the cut, the less the absolute loss in board feet, simply because fewer trees are left for the beetles to attack after a heavy cut than after a light cut.

Average Annual Mortality

In all treatments part of the pine sawtimber reserve was killed by insects at some time during the course of the study, regardless of how small a reserve was left. Even clear-cutting did not eliminate insect-caused loss entirely. Annual mortality per acre on the clear-cut plots averaged 0.036 percent of the reserve stand (table 4). On the control plots it averaged 0.441 percent, or seven times as much. The remaining treatments were intermediate between these two extremes.

The data show that cutting of all types had a marked effect in reducing the mortality. This effect shows up whether the comparisons are in terms of board feet or percent of stand. The low mortality record for the Silvicultural-Selection method was somewhat unexpected, for losses under this system should be similar to those under Insect Selection. The probable reason for the difference is the shorter length of records for the Silvicultural-Selection plots. None of these plots were measured after 10 years, the time when they were recut; whereas records on the Insect-Selection plots were maintained up to 16 years. During the first 10 years after cutting mortality under the two methods was fairly comparable.

Mortality in Successive Number of Years After Cutting

Mortality following cutting is ordinarily dated according to the calendar year in which it occurs. It can also be referred to the year of cut, and tabulated by the number of years elapsed after the cut was made. For example, for cuts made in 1938, losses in 1939 would be the mortality the first year after cutting; losses in 1940 mortality the second year; losses in 1941 the third, etc. But on plots cut in 1939, the 1940 losses would be the mortality the first year after cutting; 1941 losses mortality the second year; etc. In this report, annual mortality referred to the year of cut is termed mortality in successive numbers of years after the cutting.

Table 4.--Average volume per acre of pine sawtimber reserve killed annually by insects in methods-of-cutting plots, by method, 1939-1954[1]

Method of cutting	Number of plots	Period plot-years	Reserve volume board feet Mean	Reserve volume board feet SE	Annual mortality Board feet Mean	Annual mortality Board feet SE	Annual mortality Percent stand Mean
Control	10	115	16,682	±928	73.6	±8.6	0.441
Clear-cut	3	41	543	±169	0.2	±0.2	0.036
Heavy Forest Service	10	115	4,360	±438	4.7	±1.6	0.108
Modified Forest Service	10	115	7,096	±396	6.6	±1.7	0.093
Silvicultural-Selection	10	66	13,889	±662	5.7	±2.2	0.041
Insect Selection	5	70	14,671	±610	19.3	±5.1	0.132

1/ Summarized from Table 8, Appendix.

Data on mortality in successive numbers of years after cutting are of interest for several reasons. First, they should show whether cutting reduces the mortality and if so, by how much. Second, if patterns or trends in mortality after cutting exist, these should be revealed. A knowledge of the existence of such patterns would be useful in helping to anticipate and forestall losses. Third, such data should provide some indication of how long it takes for losses on cut areas to return to the level of those on uncut areas.

With these considerations in mind, an analysis was made of the records of insect-caused mortality in successive numbers of years after cutting under the different systems tested. Cumulative mortality in board feet was taken as the sum of the mean annual mortalities for the periods given. Cumulative percent of stand mortality was calculated from the cumulative board-foot mortality and weighted mean reserve stand volume. Weighting was according to the number of plots and number of years' records represented under each treatment; it was done to compensate for minor differences in reserve stand volume between plots.

The analysis showed that the Control sustained a greater loss than any of the methods of cutting. In the 16 years, losses in the Control totalled 1,019 board feet per acre, or 6.11 percent of the stand (table 5). Mortality was least on the Clear-cut, as one might expect. At 15 years (the total length of record for this method) it amounted to only 2.5 board feet per acre or 0.45 percent of the stand. Volume-wise the other four treatments were intermediate between these two extremes. Insect Selection, with a 16-year total of 294 board feet per acre, sustained the highest mortality second only to the Control. Total board-foot losses for the remaining three methods of cutting were well below this. On a percent of stand basis, the 16-year cumulative mortalities for the Insect Selection, Heavy Forest Service and Modified Forest Service methods did not differ greatly. Respectively, they amounted to 2.00, 1.97, and 1.72 percent, or about one-third of the percent of stand mortality in the Control.

Insect-caused mortality after cutting did not remain static under any of the systems tested. It came closest to doing so on the Clear-cut plots, where no damage whatever occurred until the eleventh year. In all the other treatments, insects killed trees nearly every year to varying degrees. Mortality in the Control was sharply upward and of considerably greater magnitude than in any of the treatments for most of the 16 years (fig. 2). By contrast, a gradual upward trend was the rule for all methods of cutting except the Clear-cut. Mortality trends, as well as magnitude of losses for a given period after cutting, were quite similar for these other methods. For example at 10 years the cumulative mortality for the Heavy Forest Service, Modified Forest Service, Silvicultural Selection and Insect Selection methods was respectively 1.06, 0.79, 0.77, and 0.80 percent of the stand.

In figure 2, differences in the slope of the curves for cut as compared to uncut plots give some indication of the extent to which mortality was reduced after cutting. A better conception of the reductions can be obtained by considering them in terms of the Control. We can postulate that if cutting had no effect, percent of stand mortality would be about the same for all treatments. Since mortality was considerably less under the different cutting methods than where no cut was made, the mortality reduction for each method can be expressed as a percent of the Control. To illustrate, with the Clear-cut method cumulative mortality the fifth year after cutting (table 5) was 0 percent of the stand, but with the Control it was 2.12 percent. The loss reduction for the Clear-cut method at 5 years was therefore 100 percent.

The Clear-cut method stands out as having produced the greatest reduction of losses (fig. 3), for obvious reasons. The effectiveness of the other four methods varied over a rather wide range during the first three years after cutting; but beginning with the fourth year all produced loss reductions within 15 percent or less of each other.

Table 5.--Cumulative insect-caused mortality of pine sawtimber reserve per acre in successive numbers of years after cutting, by method and by number of years, 1939-1954 1/

Years after cutting	Control 16,682		Clear-cut 543		Heavy Forest Service 4,360		Modified Forest Service 7,096		Silvi-cultural Selection 13,889		Insect Selection 14,671	
	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand
1	66	0.40	0	0	9	0.21	5	0.07	1	0.01	15	0.10
2	108	0.65	0	0	9	0.21	6	0.08	2	0.01	27	0.18
3	175	1.05	0	0	14	0.32	16	0.22	13	0.09	29	0.20
4	283	1.70	0	0	14	0.32	18	0.25	13	0.09	29	0.20
5	354	2.12	0	0	14	0.32	27	0.38	24	0.17	39	0.27
6	416	2.49	0	0	14	0.32	30	0.42	32	0.23	61	0.42
7	518	3.11	0	0	15	0.34	42	0.59	42	0.30	65	0.44
8	610	3.66	0	0	15	0.34	46	0.65	42	0.30	80	0.55
9	682	4.09	0	0	20	0.46	48	0.68	46	0.33	89	0.61
10	780	4.68	0	0	46	1.06	56	0.79	107	0.77	117	0.80
11	851	5.10	2.5	0.45	51	1.17	60	0.85	--	--	151	1.03
12	948	5.68	2.5	0.45	68	1.56	88	1.24	--	--	226	1.54
13	1,019	6.11	2.5	0.45	68	1.56	97	1.37	--	--	268	1.83
14	1,019	6.11	2.5	0.45	75	1.72	97	1.37	--	--	268	1.83
15	1,019	6.11	2.5	0.45	86	1.97	116	1.63	--	--	294	2.00
16	1,019	6.11	--	--	86	1.97	122	1.72	--	--	294	2.00

Method of cutting and weighted mean reserve stand volume (Bd.-ft.)

1/ Calculated from Table 9, Appendix.

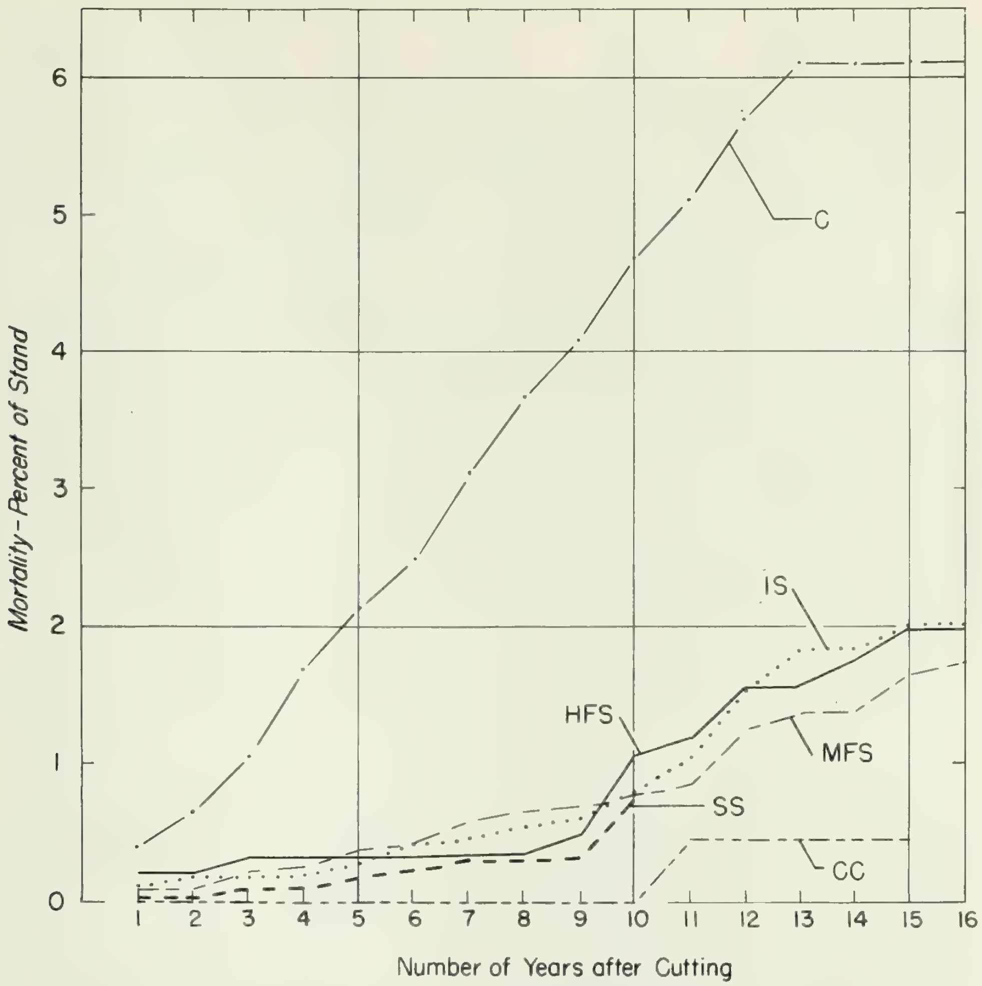

Figure 2.--Cumulative insect-caused mortality in pine saw timber reserve under different methods of cutting.

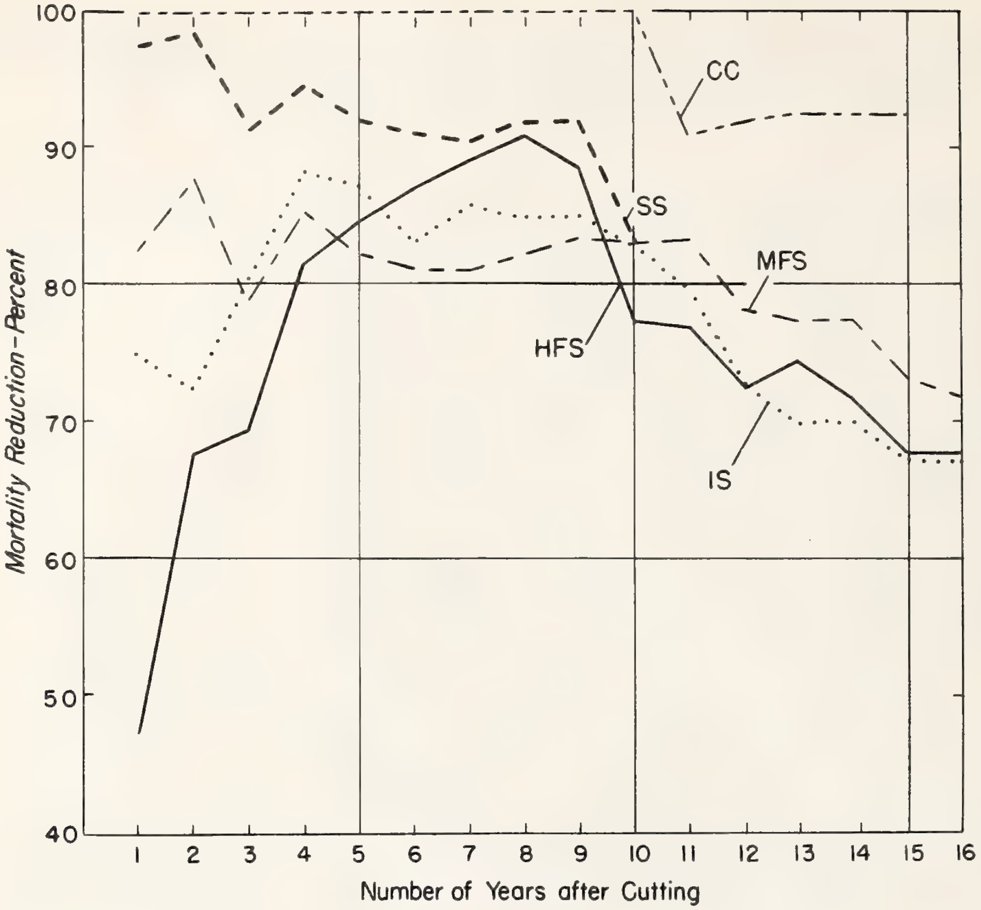

Figure 3.--Reduction in insect-caused mortality in pine sawtimber reserve under different methods of cutting as compared to control. Based on percent of stand.

The general trend in loss reduction for the four methods was about the same: an increase in the early part of the post-cutting period, followed by a general decline thereafter with the passage of time. The rising trend during the first year or so after cutting is probably the direct result of disturbances related to logging that act as a stimulus to insect attack.

The results of this study do not reveal how long any of the cutting methods can be expected to keep losses from insects from returning to the same level as the Control. However, they do provide some interesting clues to this enigma. One clue is the rate of decline in loss reduction. For the three treatments with complete records (Heavy Forest Service, Modified Forest Service, and Insect Selection) loss reduction by the 16th year was down to about 70 percent from a theoretical maximum of 100 percent. In none of these three treatments was the theoretical maximum reached. However, the average rate of decline, computed from the maximums that were reached, was 1.75 percent per year. If we assume that this rate of decline will remain the same in the future, it will take about 57 years for mortality (percent of stand) to return to the same level on all areas.

The portion of the insect-caused mortality that can be attributed solely to the high-risk element in the stand provides another clue. Cumulative mortality in the Control, as we have already seen (table 5), totaled 6.11 percent of stand in the 16 years after cutting. We can reasonably assume that only part of this mortality was due to the presence of high-risk trees, for in the three treatments mentioned above, an average cumulative mortality of 1.90 percent of stand also occurred during this same period. This happened despite the fact that the recognizable high-risk trees had been removed previously. Changes in risk in the residual stand may have contributed to this mortality, but in this particular study our information on this point is incomplete. Furniss and Hallin (1955) have shown that in comparable stands, where all of the high-risk trees were removed by sanitation-salvage logging, the volume rated as high risk 16 and 17 years after cutting was 37 percent as great as in the original stand. Where a substantially smaller reserve is left, as with the Heavy Forest Service and Modified Forest Service methods, changes in risk would probably be less frequent.

If we disregard trees that became high risk during the 16 years, the 1.90 percent can be taken to represent insect-caused mortality due to other factors than high risk. It follows that the cumulative net mortality attributable solely to high risk is 4.21 percent of the stand. Over the 16-year period this amounts to 0.263 percent per year. In old-growth pine forests like those in which this study was conducted, high-risk trees normally comprise about 15 percent of the stand. (For the Insect Selection plots they totaled 14.9 percent of stand or 2,905 board feet per acre.) If we assume that insects will kill 0.263 percent of stand in high-risk trees each year, it would take about 57 years for

them to kill all of the trees in this category. By this reasoning, cutting out the high-risk element, irrespective of the method used, would remove what the beetles could be expected to take in a like period.

In considering the degree of confidence that can be placed upon the findings reported in this section, several points should be borne in mind. One is that neither the number of years nor number of plots are identical for all treatments included in the test. As shown by the data in the Appendix, only the Control, Heavy Forest Service, and Modified Forest Service treatments are exactly comparable in both respects. The remaining three treatments are not. Also, the more recent records have the broadest base. The 16-year records, for example, are based upon but one 20-acre plot apiece, whereas the records for shorter periods are based upon successively larger numbers of plots up to a maximum of 10. Finally, it should be observed that grouping the mortality data by successive numbers of years after cutting is biologically a questionable procedure at best. The reason is that when the data are grouped in this manner it is with the assumption that mortality by calendar years is more or less constant, for there is no simple way of taking into account calendar-year fluctuations. That such fluctuations do occur is well known. When we recall that it took 10 years to establish the entire test, the possibility of errors from this source becomes apparent.

Calendar-Year Mortality

Insect-caused mortality normally fluctuates from year to year as just noted. The fluctuations have their origin in interactions between insect and environment. The records indicate that 1939-1954 was a period in which insect damage in the Control was comparatively low. If we disregard 1939, when no losses occurred on the one Control plot then available, the range in mortality was 31 to 143 board feet per acre, or 0.18 to 0.77 percent of stand (table 6). Fluctuations occurred from year to year, but they were by no means as great as those in the preceding decade (Bongberg, 1949); and on the whole they were fairly evenly distributed. If what happened in the Control can be taken as an index, it seems reasonable to conclude that extremes in the hazard of damage (for example, outbreak years) were not a factor in this study.

Mortality under the various systems of cutting did not begin to show up consistently until about 1946. The picture on the cut plots, however, is confused by two factors: (1) the broadening base each year as new plots were added annually through 1947; and (2) the decline in loss reduction resulting from cutting which, as we have seen (fig. 3), began to show up about the fourth year after cutting.

Table 6.--Annual insect-caused mortality of pine sawtimber reserve per acre, by method-of-cutting and calendar years, 1939-1954[1]/

Year	Method-of-cutting											
	Control		Clear-cut		Heavy Forest Service		Modified Forest Service		Silvicultural Selection		Insect Selection	
	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand	Bd. ft.	Pct. stand
1939	0	0	0	0	0	0	0	0	12	0.08	0	0
1940	50	0.27	0	0	0	0	0	0	0	0	37	0.25
1941	143	0.77	0	0	10	0.20	0	0	0	0	20	0.14
1942	37	0.22	0	0	0	0	0	0	5	0.03	0	0
1943	69	0.41	0	0	0	0	2	0.03	0	0	2	0.01
1944	31	0.18	0	0	0	0	0	0	0	0	0	0
1945	115	0.70	0	0	0	0	2	0.03	0	0	0	0
1946	71	0.42	0	0	0	0	0	0	6	0.05	10	0.07
1947	93	0.56	0	0	2	0.05	4	0.06	8	0.06	18	0.12
1948	119	0.72	0	0	9	0.21	24	0.34	6	0.04	23	0.16
1949	36	0.22	0	0	8	0.19	12	0.17	23	0.16	66	0.45
1950	96	0.58	0	0	23	0.53	9	0.13	10	0.07	42	0.29
1951	114	0.69	2.5	0.45	0	0	3	0.04	0	0	55	0.38
1952	57	0.35	0	0	2	0.05	8	0.11	0	0	0	0
1953	41	0.25	0	0	8	0.19	6	0.08	0	0	27	0.18
1954	41	0.25	0	0	0	0	6	0.08	0	0	0	0

1/ Condensed from Table 10, Appendix.

The records of calendar-year mortality on the Control plots were compared with similar records from the five untreated compartments on the Experimental Forest to determine if they presented the same picture. The compartments aggregate about $2\frac{1}{2}$ times the area of the Control plots, but otherwise are similar to them as to stand and treatment. The data for both were taken in the same manner, and at about the same time. They reveal some rather wide differences between plots and compartments during the first three, and most of the last six years (fig. 4). Differences during the first three years are not surprising, for the number of plots then was small. This was not true later, for beginning with 1948, each year's plot record is a mean of ten replicates. Consequently, the disparity between plots and compartments in the last 6 years is unexpected. The compartment records are considered more reliable because of their broader base. These results seem to justify the observation made earlier that the small number and size of the plots was one of the major weaknesses in the test.

Loss in Relation to Tree Class

When the methods-of-cutting study was started, it was thought that information on tree classes might furnish some indication of the types of trees most likely to die in the years following cutting. For this reason the trees on the plots were classified by the Dunning, Keen, and Risk systems. An attempt was made to analyze the mortality data to determine the distribution of loss by the different classification systems and methods of cutting. The chief difficulty encountered was too few data--to cite an extreme, but one entry for the Clear-cut plots. In addition, inadequacies in some records were uncovered, further reducing what was available. Because of this, the records by the Keen system, with its 16 classes, were eliminated from consideration. Those for the Dunning and Risk systems are summarized in table 7.

For the Control, Class 5 trees accounted for by far the largest amount of mortality (64 percent of the volume and 63 percent of the number of trees) under the Dunning system. Next was Class 3 (12 percent by volume and by number of trees). Under the Risk system the largest amount of mortality (75 percent) was in Risk 3 and 4 as one would expect. These results are probably not far out of line.

For the different methods of cutting, Dunning Class 5, 3, and 1 trees, generally in that order, sustained the highest mortality. The exception was the Clear-cut. Under the Risk system most of the mortality was in Risk 1 and 2. The relatively high proportion of the mortality in Dunning 1 and Risk 1 was not expected and is difficult to account for. In view of the meager data for the cut plots these findings should probably be considered indicative rather than conclusive.

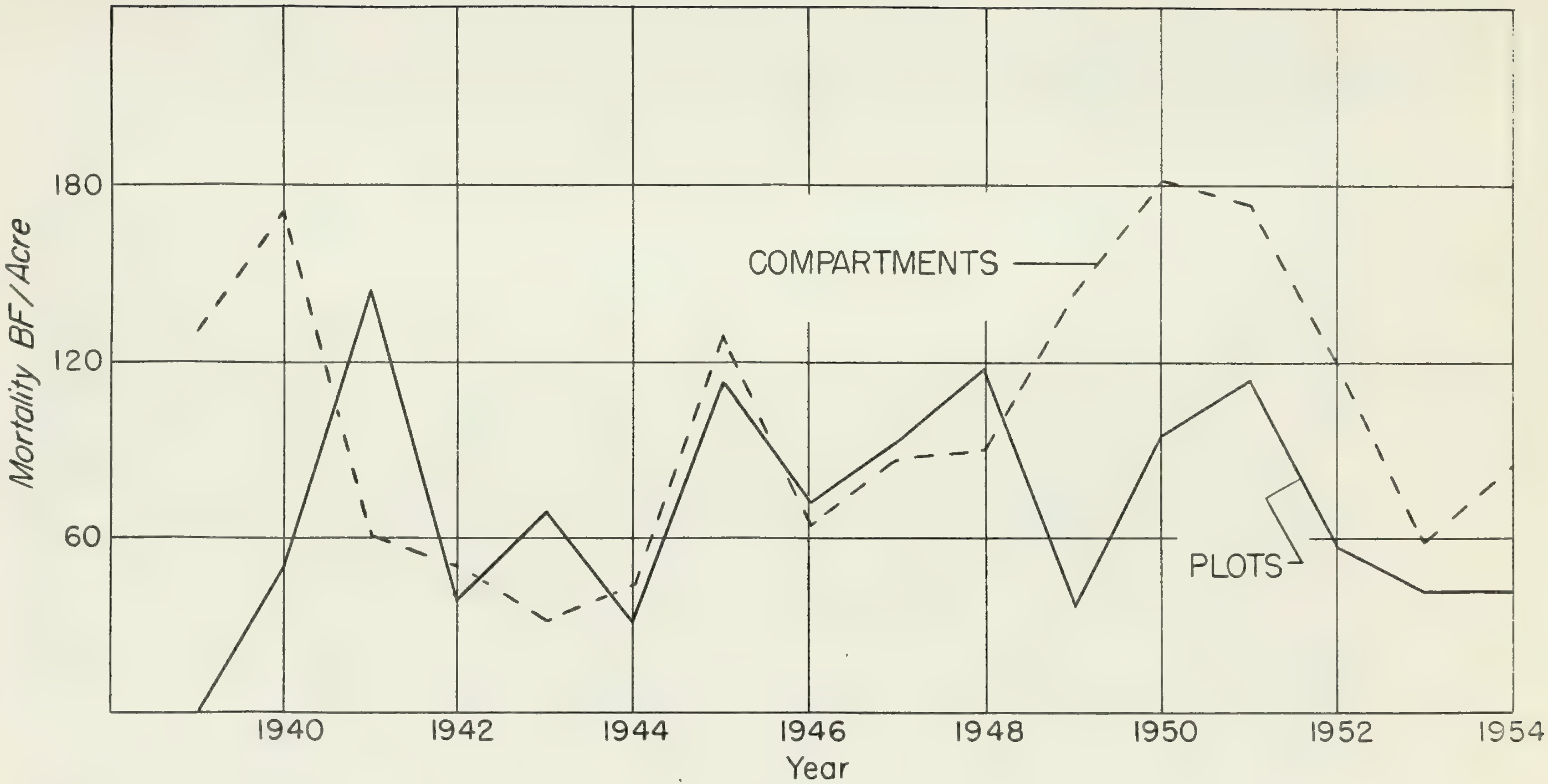

Figure 4.--Annual insect-caused mortality in pine sawtimber on uncut plots and compartments.

Table 7.--Percent of pine volume killed by insects after cutting, by Dunning and Risk classes and by method-of-cutting, 1939-1952[1]

Method of cutting	Basis[2]	Dunning Class 1	2	3	4	5	6	7	Risk Class Basis[2]	Risk Class 1	2	3	4
	Bd.-ft.	Percent							Bd.-ft.	Percent			
Control	153,182 (131)	3	7	12	7	64	2	5	151,826 (128)	16	9	19	56
Clear-cut	150 (1)	--	100	--	--	--	--	--	150 (1)	100	--	--	--
Heavy Forest Service	16,483 (19)	21	--	26	5	27	5	16	8,967 (14)	72	21	7	--
Modified Forest Service	12,740 (22)	32	14	18	9	23	--	4	11,507 (19)	58	32	10	--
Silvicultural Selection	12,894 (21)	14	5	19	5	33	10	14	9,297 (12)	42	58	--	--
Insect Selection	24,232 (22)	5	--	23	9	59	--	4	13,676 (14)	36	64	--	--

1/ Data in this table are for 14 years only. Discrepancies in basic volume for Dunning as compared to Risk are due to incomplete information on tree classes for some of the trees killed.

2/ Numbers in parenthesis are number of trees.

DISCUSSION

In the thirties, when this study was started, much of the eastside pine forest had not yet been cut, and the importance of having some means of preventing insect-caused losses in ponderosa pine was paramount. Too often in attempts to follow the usual orderly process of converting the unmanaged old growth to a managed condition, it was found that by the time a management unit was to be harvested, insects had taken a heavy toll. Before cutting could be scheduled, bark beetles, as they have done from immemorial, often killed many trees, thereby seriously disrupting management plans. This same situation prevails today on the remaining one-quarter to one-third of the 4 million acres in California's Eastside Sierra subregion that can still be considered virgin. However much of the area once occupied by old growth has since been put under some form of forest management.

Hallin (1959, p. 36) has pointed out that reducing insect-caused losses in old-growth eastside pine forests is the first step in the process of converting these forests to a managed condition. Bongberg (1949) has shown that the Insect Selection method, which later came to be called sanitation-salvage, is an eminently practical means of accomplishing this. As a result, sanitation-salvage cutting has been widely applied, not only in California, but elsewhere throughout the range of ponderosa pine where bark beetles are a problem.

The success of sanitation-salvage has more than met the expectations of its originators. The full story of its effectiveness during the first two decades since it was tried at Blacks Mountain remains to be told. Loss reductions accomplished with this method during the first decade after cutting are well documented by Bongberg (1949). The present analysis, though based only on records from part of the studies being conducted on the Experimental Forest, confirms Bongberg's findings and carries the record forward another half decade. It shows that 16 years after cutting, losses on the sanitation-salvage cut plots were still less than one-third those on the uncut plots. And it suggests that the effects of treatment may last for half a century.

What effect light cutting would have on the subsequent pattern of insect-caused loss was not the only question to be answered when this study was started. Much conjecture centered upon whether or not medium or heavy cutting had a good or bad effect on bark beetle activity. The results of the present study show that: (1) insect-caused mortality after cutting was materially less on all cutover plots than on uncut, regardless of whether the cut was light, medium, or heavy; and (2) the percent-of-stand mortality generally did not differ appreciably between methods, apart from the Control, during the post-cutting period. These findings are essentially the same as those reported by Keen (1955) from a more general analysis of insect damage after different types of cutting in other ponderosa pine stands.

Silvicultural practice has moved away from most of the methods of cutting included in this study except sanitation-salvage. Unit Area Control is the currently recommended system of management for the eastside pine type (Hallin, 1959). However, extensive areas still exist that were cut by these other methods. Consequently it is important to know that the particular cutting system used has no special effect on the loss pattern.

The design of the tests reported here was probably adequate to reflect pronounced differences in insect-caused mortality after cutting; but its adequacy for revealing small differences that could be due either to treatment, yearly fluctuations in insect abundance or other causes is doubtful. Because of this, records of insect-caused mortality on the 20-acre methods-of-cutting plots at Blacks Mountain are being brought to a close with this report. Studies of mortality on sanitation-salvage cut and uncut compartments of the Experimental Forest, apart from the methods-of-cutting plots, are being continued, primarily to determine the length of effectiveness of sanitation-salvage as an insect control measure. For insect-caused mortality in relation to the remaining methods of cutting represented in the plot tests, this is a completion report.

SUMMARY

One of the uncertainties confronting foresters concerned with the management of ponderosa pine is the effect of timber harvesting methods on the pattern of insect-caused mortality in the residual stand. To shed some light on this problem, an analysis was made of mortality records from a methods-of-cutting study in progress on the Blacks Mountain Experimental Forest.

The data analyzed were from replicated 20-acre plots in old-growth ponderosa pine stands. The plots were established by the Division of Forest Management Research over a 10-year period (1938-1947) to test the effects of five methods of cutting in achieving maximum sustained yield. Mortality was measured annually for 16 years after cutting (1939-1954) by the Division of Forest Insect Research.

Of the total pine sawtimber volume that died, insects (chiefly the western pine beetle) accounted for about two-thirds. In the control plots, beetles killed annually an average volume of 73.6 board feet per acre, or 0.441 percent of stand. Mortality in the treatments varied from 0.2 to 19.3 board feet per acre, and 0.036 to 0.132 percent of stand.

Cumulative insect-caused mortality in successive numbers of years after cutting followed the same general trend on cutover plots as on uncut, except where clear cutting was done. Clear cutting resulted in the greatest reduction in the volume of timber killed;

92 percent by 15 years. Reductions attributable to other methods varied considerably in the first three years, but by 16 years most were about 70 percent.

The findings indicate that reducing the toll taken by insects is more a matter of getting to the susceptible trees before the beetles do than to the particular method of cutting used. Projections of the data suggest that once the susceptible trees are removed, mortality from insects may not return to precutting levels for more than 50 years.

The design of the study did not prove altogether satisfactory for measuring accurately small differences in mortality such as those due to treatment, changes in insect abundance, or other causes. Chief drawbacks were the small size and number of plots, the time required for plot establishment, and the close proximity of treatments within blocks.

REFERENCES

Anonymous.
1938a. The Blacks Mountain Experimental Forest, a sustained yield experiment in ponderosa pine in northeastern California. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., 16 pp., illus. (Processed.)

_____ 1938b. Methods-of-cutting demonstration plots. U. S. Forest Serv. Calif. Forest and Range Expt. Sta. 3 pp., illus., (Processed.)

Bongberg, J. W.
1939. Loss prevention studies, Blacks Mountain Experimental Forest, season of 1938. U. S. Bur. Ent. and Plant Quar., Forest Insect Lab., 11 pp., illus. (Typed.)

_____ 1949. Results of 10 years of bark-beetle control by logging high risk trees, Blacks Mountain Experimental Forest, Lassen County, Calif. U. S. Bur. Ent. and Plant Quar., Forest Insect Lab., 11 pp., I-VII, illus. (Processed.)

Downing, G. L.
1956. Instructions for conducting the annual cruise of insect-caused losses on the Blacks Mountain Experimental Forest. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., 24 pp., illus. (Processed.)

Dunning, Duncan
1937. Outline plan of development and research, Blacks Mountain Experimental Forest. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., 24 pp. (Typed.)

Furniss, M. M., and Hallin, W. E.
1955. Development of high-risk trees in ponderosa and Jeffrey pine stands following sanitation-salvage cutting. U. S. Forest Serv., Calif. Forest and Range Expt. Sta. Res. Note 94, 2 pp. (Processed.)

Hallin, W. E.
1959. The application of unit area control in the management of ponderosa-Jeffrey pine at Blacks Mountain Experimental Forest. U. S. Dept. Agr. Tech. Bul. 1191, 96 pp., illus.

Hasel, A. A.
1938. Plan for methods-of-cutting study, Blacks Mountain sustained yield project. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., 16 pp., illus. (Typed.)

Keen, F. P.
1955. A progress report on insect mortality studies on cut-over ponderosa pine lands. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., 17 pp. (Processed.)

Salman, K. A.
1938. Susceptibility classification for ponderosa and Jeffrey pine, eastside forests of northeastern California. U. S. Bur. Ent. and Plant Quar., Forest Insect Lab., 3 pp., illus. (Typed.)

APPENDIX

Table 8.--Average annual insect-caused mortality of pine sawtimber reserve per acre during period after cutting, by plots. 1939-1954

CONTROL

Plot	Reserve stand, board feet	Period years	Annual mortality: Board feet	Annual mortality: Percent stand
38-2	21,684	16	94	0.43
39-5	15,533	15	74	0.48
40-2	18,335	14	90	0.49
41-4	12,495	13	65	0.52
42-6	17,037	12	49	0.29
43-4	15,690	11	80	0.51
44-1	14,619	10	58	0.40
45-3	20,162	9	23	0.11
46-2	13,043	8	103	0.79
47-2	15,763	7	96	0.61
Wtd. Mean[1/]	16,682		73.6	0.441
Mean	16,436			
SE	± 928		±8.6	±0.051

CLEAR CUT

Plot	Reserve stand, board feet	Period years	Annual mortality: Board feet	Annual mortality: Percent stand
39-4	503	15	0	0
40-1	299	14	0.6	0.20
42-1	877	12	0	0
Wtd. Mean[1/]	543		0.2	0.036
Mean	559			
SE	±169		±0.19	±0.065

See footnote at end of table.

(Continued)

Table 8.--Average annual insect-caused mortality of pine sawtimber reserve per acre during period after cutting, by plots. 1939-1954

HEAVY FOREST SERVICE

Plot	Reserve stand, board feet	Period years	Annual mortality: Board feet	Annual mortality: Percent stand
38-4	5,469	16	13	0.24
39-6	3,552	15	1	0.03
40-6	5,655	14	10	0.18
41-2	5,233	13	0	0
42-2	1,351	12	0	0
43-1	5,434	11	5	0.09
44-4	2,798	10	1	0.04
45-2	4,509	9	0	0
46-3	4,347	8	3	0.07
47-1	4,873	7	13	0.27
Wtd. Mean[1/]	4,360		4.7	0.108
Mean	4,322			
SE	±438		±1.6	±0.029
MODIFIED FOREST SERVICE				
38-1	8,247	16	7	0.08
39-3	5,632	15	0	0
40-4	8,428	14	6	0.07
41-5	8,190	13	21	0.26
42-4	5,230	12	0	0
43-2	7,152	11	13	0.18
44-2	5,626	10	0	0
45-1	7,186	9	0	0
46-4	6,694	8	11	0.16
47-4	8,467	7	8	0.09
Wtd. Mean[1/]	7,096		6.6	0.093
Mean	7,085			
SE	±396		±1.7	±0.023

See footnote at end of table.

(Continued)

Table 8.--Average annual insect-caused mortality of pine sawtimber reserve per acre during period after cutting, by plots. 1939-1954

SILVICULTURAL SELECTION

Plot	Reserve stand, board feet	Period years	Annual mortality	
			Board feet	Percent stand
38-3	15,616	3	4	0.03
39-2	10,645	2	0	0
40-5	15,277	10	19	0.12
41-3	14,718	5	0	0
42-3	11,687	4	0	0
43-3	10,923	9	6	0.05
44-3	12,622	9	3	0.02
45-4	14,502	9	0	0
46-1	16,714	8	13	0.08
47-3	14,188	7	0	0
Wtd. Mean 1/	13,889		5.7	0.041
Mean	13,689			
SE	±662		±2.2	±0.015

INSECT SELECTION

Plot	Reserve stand, board feet	Period years	Board feet	Percent stand
38-5	16,742	16	36	0.22
39-1	12,975	15	26	0.20
40-3	14,153	14	7	0.05
41-1	14,728	13	17	0.12
42-5	14,575	12	5	0.03
Wtd. Mean 1/	14,671		19.3	0.132
Mean	14,635			
SE	±610		±5.1	±0.034

1/ Weighted by number of years. Example: To compute weighted mean reserve stand, multiply reserve stand times number of years for each plot; add products and divide result by total number of years for all plots.

Table 9.--Average annual insect-caused mortality of pine sawtimber reserve per acre in successive years after cutting, by number of years. 1939-1954

CONTROL

Years after cutting	No. plots	Reserve stand, board feet	Annual mortality	
			Board feet	Percent stand
1	10	16,436	66	0.40
2	10	16,436	42	0.26
3	10	16,436	67	0.41
4	10	16,436	108	0.66
5	10	16,436	71	0.43
6	10	16,436	62	0.38
7	10	16,436	102	0.62
8	9	16,510	92	0.56
9	8	16,944	72	0.42
10	7	16,484	98	0.59
11	6	16,795	71	0.42
12	5	17,017	97	0.57
13	4	17,012	71	0.42
14	3	18,517	0	0
15	2	18,609	0	0
16	1	21,684	0	0
		CLEAR CUT		
1	3	559	0	0
2	3	559	0	0
3	3	559	0	0
4	3	559	0	0
5	3	559	0	0
6	3	559	0	0
7	3	559	0	0
8	3	559	0	0
9	3	559	0	0
10	3	559	0	0
11	3	559	2.5	0.45
12	3	559	0	0
13	2	401	0	0
14	2	401	0	0
15	1	503	0	0

(Continued)

Table 9.--Average annual insect-caused mortality of pine sawtimber reserve per acre in successive years after cutting, by number of years. 1939-1954

HEAVY FOREST SERVICE

Years after cutting	No. plots	Reserve stand, board feet	Annual mortality	
			Board feet	Percent stand
1	10	4,322	9	0.21
2	10	4,322	0	0
3	10	4,322	5	0.12
4	10	4,322	0	0
5	10	4,322	0	0
6	10	4,322	0	0
7	10	4,322	1	0.02
8	9	4,261	0	0
9	8	4,250	5	0.12
10	7	4,213	26	0.62
11	6	4,449	5	0.11
12	5	4,252	17	0.40
13	4	4,977	0	0
14	3	4,892	7	0.14
15	2	4,511	11	0.24
16	1	5,469	0	0

MODIFIED FOREST SERVICE

Years after cutting	No. plots	Reserve stand, board feet	Board feet	Percent stand
1	10	7,085	5	0.07
2	10	7,085	1	0.01
3	10	7,085	10	0.14
4	10	7,085	2	0.03
5	10	7,085	9	0.13
6	10	7,085	3	0.04
7	10	7,085	12	0.17
8	9	6,932	4	0.06
9	8	6,961	2	0.03
10	7	6,929	8	0.12
11	6	7,147	4	0.06
12	5	7,145	28	0.39
13	4	7,624	9	0.12
14	3	7,436	0	0
15	2	6,940	19	0.27
16	1	8,247	6	0.07

(Continued)

Table 9.--Average annual insect-caused mortality of pine sawtimber reserve per acre in successive years after cutting, by number of years. 1939-1954

SILVICULTURAL SELECTION

Years after cutting	No. plots	Reserve stand, board feet	Annual mortality	
			board feet	Percent stand
1	10	13,689	1	0.01
2	10	13,689	1	0.01
3	9	14,027	11	0.08
4	8	13,829	0	0
5	7	14,135	11	0.08
6	6	14,038	8	0.06
7	6	14,038	10	0.07
8	5	14,007	0	0
9	4	13,331	4	0.03
10	1	15,277	61	0.39

INSECT SELECTION

Years after cutting	No. plots	Reserve stand, board feet	Annual mortality, board feet	Annual mortality, Percent stand
1	5	14,635	15	0.10
2	5	14,635	12	0.08
3	5	14,635	2	0.01
4	5	14,635	0	0
5	5	14,635	10	0.07
6	5	14,635	22	0.15
7	5	14,635	4	0.03
8	5	14,635	15	0.10
9	5	14,635	9	0.06
10	5	14,635	28	0.19
11	5	14,635	34	0.23
12	5	14,635	75	0.51
13	4	14,650	42	0.29
14	3	14,623	0	0
15	2	14,859	26	0.17
16	1	16,742	0	0

Table 10.--Average annual insect-caused mortality of pine sawtimber reserve per acre by calendar years. 1939-1954

CONTROL

Year	No. plots	Reserve stand, board feet	Annual mortality	
			Board feet	Percent stand
1939	1	21,684	0	0
1940	2	18,609	50	0.27
1941	3	18,517	143	0.77
1942	4	17,012	37	0.22
1943	5	17,017	69	0.41
1944	6	16,795	31	0.18
1945	7	16,484	115	0.70
1946	8	16,944	71	0.42
1947	9	16,510	93	0.56
1948	10	16,436	119	0.72
1949	10	16,436	36	0.22
1950	10	16,436	96	0.58
1951	10	16,436	114	0.69
1952	10	16,436	57	0.35
1953	10	16,436	41	0.25
1954	10	16,436	41	0.25

CLEAR CUT

Year	No. plots	Reserve stand, board feet	Board feet	Percent stand
1939	0	--	--	--
1940	1	503	0	0
1941	2	401	0	0
1942	2	401	0	0
1943	3	559	0	0
1944	3	559	0	0
1945	3	559	0	0
1946	3	559	0	0
1947	3	559	0	0
1948	3	559	0	0
1949	3	559	0	0
1950	3	559	0	0
1951	3	559	2.5	0.45
1952	3	559	0	0
1953	3	559	0	0
1954	3	559	0	0

(Continued)

Table 10.--Average annual insect-caused mortality of pine sawtimber reserve per acre by calendar years. 1939-1954

HEAVY FOREST SERVICE

Year	No. plots	Reserve stand, board feet	Annual mortality board feet	Annual mortality Percent stand
1939	1	5,469	0	0
1940	2	4,511	0	0
1941	3	4,892	10	0.20
1942	4	4,977	0	0
1943	5	4,252	0	0
1944	6	4,449	0	0
1945	7	4,213	0	0
1946	8	4,250	0	0
1947	9	4,261	2	0.05
1948	10	4,322	9	0.21
1949	10	4,322	8	0.19
1950	10	4,322	23	0.53
1951	10	4,322	0	0
1952	10	4,322	2	0.05
1953	10	4,322	8	0.19
1954	10	4,322	0	0

MODIFIED FOREST SERVICE

Year	No. plots	Reserve stand, board feet	Annual mortality board feet	Annual mortality Percent stand
1939	1	8,247	0	0
1940	2	6,940	0	0
1941	3	7,436	0	0
1942	4	7,624	0	0
1943	5	7,145	2	0.03
1944	6	7,147	0	0
1945	7	6,929	2	0.03
1946	8	6,961	0	0
1947	9	6,932	4	0.06
1948	10	7,085	24	0.34
1949	10	7,085	12	0.17
1950	10	7,085	9	0.13
1951	10	7,085	3	0.04
1952	10	7,085	8	0.11
1953	10	7,085	6	0.08
1954	10	7,085	6	0.08

(Continued)

Table 10.--Average annual insect-caused mortality of pine sawtimber reserve per acre by calendar years. 1939-1954

SILVICULTURAL SELECTION

Year	No. plots	Reserve stand, board feet	Annual mortality	
			board feet	Percent stand
1939	1	15,616	12	0.08
1940	2	13,131	0	0
1941	3	13,846	0	0
1942	2	14,998	5	0.03
1943	3	13,894	0	0
1944	4	13,151	0	0
1945	5	13,045	0	0
1946	6	13,288	6	0.05
1947	5	14,008	8	0.06
1948	6	14,044	6	0.04
1949	6	14,044	23	0.16
1950	6	14,044	10	0.07
1951	5	13,790	0	0
1952	5	13,790	0	0
1953	4	14,507	0	0
1954	3	15,135	0	0

INSECT SELECTION

Year	No. plots	Reserve stand, board feet	Annual mortality, board feet	Percent stand
1939	1	16,742	0	0
1940	2	14,859	37	0.25
1941	3	14,623	20	0.14
1942	4	14,650	0	0
1943	5	14,635	2	0.01
1944	5	14,635	0	0
1945	5	14,635	0	0
1946	5	14,635	10	0.07
1947	5	14,635	18	0.12
1948	5	14,635	23	0.16
1949	5	14,635	66	0.45
1950	5	14,635	42	0.29
1951	5	14,635	55	0.38
1952	5	14,635	0	0
1953	5	14,635	27	0.18
1954	5	14,635	0	0

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